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ORIGINAL PAPER

Nest-site selection pattern of *Grus japonensis* in Zhalong Nature Reserve of northeast China

WU Qing-ming • ZOU Hong-fei

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Abstract: Nest-site selection patterns of Red-crowned cranes (*Grus japonensis*) and the effects of environmental variables were studied during the years of 2002–2008 in Zhalong Nature Reserve, Qiqihar city, northeast China. The nest-site selection pattern of Red-crowned cranes included two orders and three choices: the choice of nest-site habitat type within the macro-habitat order, nest zone selection and nest-site micro-habitat selection within the micro-habitat order. Various habitats (such as Carex swamps and reed fire districts) can be selected as the nest sites for Red-crowned cranes, of which reed swamps (93.15%) are given a preference. Factor Analysis reveals that the micro-habitat selection are affected by four main factors: fire, security (concealment / disturbance), incubation (conditions, nest-material), and food. Further analysis reveals that Red-crowned cranes have certain adaptability to the changes of nesting habitat quality in the Zhalong wetlands. In conclusion, fire, reeds, and water were the most important variables for nest-site habitat selection of Red-crowned Cranes in Zhalong Nature Reserve.

Keywords: conservation factor analysis; nest-site selection pattern; Red-crowned crane; Zhalong Nature Reserve

Introduction

Successful reproduction is one of the key breeding activities for birds and consequence of this activity has a direct relationship with changes in population (Lack 1933). In birds, the nest is the location for incubation, and environmental variables around nest affect the success of breeding (Robertson 1995; Rangel-salazar et al. 2008; Dalley et al. 2009). Thus, a nest-site selection is clearly vital, on which natural selection must have exerted some considerable influence (Cody 1981), and identification of nest-site habitat features influencing reproduction and survival are essential for the management and long-term viability of bird populations (Svardson 1949). Zhalong wetland is a wetland of international importance and also a major breeding location for *Grus japonensis* (Su et al. 2000). Since 1997, Zhalong wetland has suffered from various serious environmental disturbances such as drought and fires. Fire happens every year in the Zhalong wetlands and this allows for the comparison of habitat quality before and after fires, especially in quality and quantity reed swamps. Reed swamps are the main nesting habitat for Red-crowned Cranes (*G. japonensis*), but they are also the main economic source for local residents (Zou et al. 2006; 2009). These factors have greatly affected the survival and reproduction of breeding population of Red-crowned cranes in the Zhalong wetlands (Zou et al. 2003; 2007a).

Nest-site selection for Red-crowned Cranes has been the subject of many previous studies (Li et al. 1999; Wan et al. 2002; Zou et al. 2003; Cao et al. 2008; Qin et al. 2008; Jiang et al. 2009; Qin et al. 2009; Zou et al. 2009). For example, Li et al. (1999) and Zou et al. (2003) respectively documented the nest-site selection of Red-crowned Cranes in 1996 and 2002, but they only reported data of a year, with very limited information. In addition, Wan et al. (2002) studied the effects of habitat fragmentation on nesting site selection in Shuangtaihekou National Natural Reserve in Liaoning Province during April and May of 1985, 1995 and 1998. Qin et al. (2008 & 2009) analyzed the spatial distribution of nest-sites using Voronoi diagram and 3S techniques in Zhalong National Natural Reserve in 1996 and 2003-2007; Zou et al. (2009) also reported the internal distribution pattern of the nests and home of Red-crowned Cranes based on the distribution distance index and nearest neighbor analysis in Zhalong Nature Reserve from April to May for the years 2002–2004 and 2006. Cao et al. (2008) analyzed the habitat suitability change of red-crowned crane due to habitat loss and fragmentation by se-

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WU Qing-ming • ZOU Hong-fei (✉)
College of Wildlife Resource, Northeast Forestry University, Harbin 150040, P.R. China. Email: hongfeizou@163.com

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lecting a series of landscape pattern indices based on the habitat suitability maps in Yellow River Delta Nature Reserve, Shandong Province, China. Jiang et al. (2009) developed a model of nest-site selection based on RS, GIS and GPS techniques at Zhalong wetland, China, but the results remain inconclusive due to discrepancies in the methodology (This model used the landsat image data on 30 August, 2003; whereas cranes incubate during the months of March and May and rear the offspring during June to September. As a consequence, the landsat image data may not accurately reflect the habitat status during the incubation period). Despite these previous studies, there still remains little long-term information of nest-site habitat selection pattern for Red-crowned Cranes. In order to design a management strategy for the timely conservation of Red-Crowned Cranes in Zhalong Nature Reserve, long-term data on the physical features of nest sites and preference of nesting micro-habitats is needed. This study investigates the nest-site selection pattern of Red-crowned Cranes and assesses the effect of environmental variables on its nest-site selection in Zhalong Nature Reserve of northeast China.

Materials and methods

Study area

Zhalong Nature Reserve (46°52′N–47°32′N, 123°47 E′–124°37′E) is situated in the southeast of Qiqihar city in Heilongjiang Province, northeastern China. It was listed as a “Wetland of International Importance” (especially as waterfowl habitat) in 1992. The region has a continental, semiarid and monsoon climate. The total area of the reserve is 2 100 km^2 with the average altitude of 144.0 m above sea level. Reed marshes cover an area of 80%–90% of the Reserve, while carex swamp (*Carex pseudoeuraica* swamp and bulrush swamp), meadows, and grassland make up the remainder. Local people compete with cranes for reeds and fish, which are the largest economic resources in the area. Furthermore, long-term drought and annual wildfires have led to a decrease in the height and density of the remaining reeds. These factors have influenced the survival and reproductive success of multiple waterfowl species and in particular, Red-Crowned Cranes (Zou et al. 2007b). Our surveys and the main observations were focused on three sites within the Nature Reserve: (1) “Zhalong observation site” which is the main breeding location for Red-crowned Cranes, (2) “Laomachang observation site” where only several breeding pairs, and (3) “Dangnai observation site” which also have a limited number of breeding pairs.

Survey

We defined the hatch period as the time range from when the first egg is laid to when the last chick is hatched. We searched for breeding pairs of Red-crowned Crane with 8-20x binocular, 20-40x binocular and 20-60x monocular in the three main observation sites of breeding Red-crowned Cranes within the Nature Reserve from March to May of 2002–2008. We observed the breeding behavior of Red-crowned Cranes, and identified individual breeding pairs, their nesting ranges, and nesting site habitat type by various behavior characteristics (i.e. territorial behavior, exchanging incubation behavior, etc.). We ascertained nest-site positions on foot by the natural markers on the ground and the use of range finder, 20x and 60x telescopes, positioned by GPS. We then started measuring the environmental variables by plot sampling.

Plots were circular and centered on Red-crowned crane nests. We did two perpendicular transects through the center point in arbitrary directions, and measured environmental variables in a 1 m × 1 m at 5 m and 10 m from the center point along the transect. The environmental variables measured (Zou et al. 2005; Zou et al. 2006; Wu et al. 2009) are described as follows:

(1) The distance to frequently disturbed zones from human activity (km) (X_1): the distance between nest-site and the nearest zone of frequent human activity (for instance, the settlement, road, etc);

(2) The distance to disturbance zone with infrequent human activity or mad-made structure (km) (X_2): the distance between nest-site and the nearest zone with infrequent human activity or man-made structure (such as wickiup for looking after fish, fishing site, dyke, man-made ditch, large driveway, and so on);

(3) The distance from a lake (m) (X_3) and the lake area (m^2) (X_4): the distance between nest-site and the nearest lake that is more than 1 m^2 in area, and the area of lake;

(4) The distance from burnt zone (km) (X_5) and the burnt area (m^2) (X_6): the distance between nest-site and the nearest burnt zone within 2.5 km, and the area of burnt zone;

(5) The distance to remnant reed cluster (m) (X_7), and the remnant reed cluster area (m^2) (X_8), density (strain/m^2) (X_9) and height (cm) (X_{10}): the distance between nest-site and the nearest remnant reed cluster, and the area, density and average natural height of the remnant reeds cluster;

(6) Water depth (cm) (X_{11}): the average natural water depth in plot sampling;

(7) Vegetation height (cm) (X_{12}): the average natural height of vegetation within the plot;

(8) Vegetation density (strain/m^2) (X_{13}): the average density of vegetation within a plot;

(9) Vegetation coverage (%) (X_{14}): the base area of vegetation in plot sampling;

(10) Altitude (m) (X_{15}): the average altitude of the plot.

Statistical analyses

We located 73 Red-crowned Cranes nests, but the environmental variables for only 61 nests were measured and recorded. First, a univariate analysis of 15 independent environmental variables was performed to ascertain the specificity and significance of nest-site habitat selection of Red-crowned Cranes, using the One-way ANOVA and Independent-Samples T Test. Secondly, the influence factor on nest-site habitat selection was analyzed using the Data Reduction - Factor Analysis. All statistical analyses were carried out with SPSS 11.5. All data were presented as mean ± se.

Results

Earliest recorded hatch

The earliest recorded hatch time for Red-crowned Cranes in Zhalong Nature Reserve during seven consecutive years were: March 22, 2002, April 3, 2003, March 31, 2004, April 2, 2005, March 22, 2006, March 22, 2007, and April 1, 2008. No significant differences in the earliest hatch time were found in the different years.

Habitat types of nesting-sites

We located and marked with GPS 73 nests of Red-crowned Cranes through repetitive observation of foraging activity during incubation. The nesting rate differed in the different habitat types (see Fig. 1). The majority of the nests were located in reed swamps (93.15%); the same pair of breeding cranes nested in a different site each year, but the nest range did not change unless there was a significant environmental change.

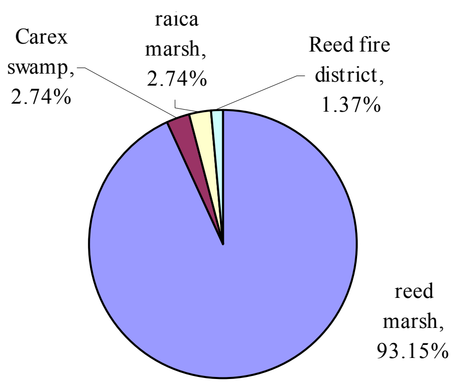

Fig. 1 The nest-site habitat types for Red-crowned Cranes

Environmental features of nest-site habitat

Variance analysis revealed that 15 environmental variables were statistically significant ($F_{\text{statistic}}$=80.242>$F_{0.01}$ =1.490), indicating that the nest-site selection of Red-crowned Cranes is not random. There were notable differences between the environmental variables in the nest-site habitat of Red-crowned Cranes and the contrast plot sampling (Table 1). The disturbance distance 1 (zone with frequent human activity), disturbance distance 2 (zone with infrequent human activity), distance to lakes, the area of burnt zone, the density of remnant reed cluster, the height of remnant reed cluster, vegetation height, vegetation coverage, altitude, are the factors having extremely marked differences (p < 0.01); the lake area and the area of remnant reed cluster are two factors with statistical differences (p < 0.05); the distance to burnt zone, the distance to remnant reed cluster, water depth, vegetation density are the factors that had no statistical differences (Table 2).

Table 1. The distribution of the environmental variables between Red-crowned Cranes nest-site and comparison plot sampled

Environ-mental variables	Interval	Red-crowned Cranes (n=61)		Comparison plot (n=621)	
		Frequence	(%)Proportion	Frequence	(%)Proportion
X_1	[0, 0.5]	5	8.20	22	3.54
	(0.5, 1.0]	9	14.75	74	11.92
	(1.0, 1.5]	9	14.75	94	15.14
	(1.5, 2.0]	9	14.75	95	15.30
	(2.0, 3.0]	17	27.87	114	18.36
	(3.0, + ∞)	12	19.68	222	35.74
X_2	[0, 0.3]	10	16.39	139	22.38
	(0.3, 0.5]	19	31.15	110	17.72
	(0.5, 1.0]	18	29.51	99	15.95
	(1.0, 1.5]	8	13.11	91	14.65
	(1.5, 2.0]	3	4.92	91	14.65
	(2.0, + ∞)	3	4.92	91	14.65
X_3	[0, 30]	14	22.95	138	22.22
	(30, 50]	33	54.10	39	6.28
	(50, + ∞)	14	22.95	444	71.50
X_4	[0, 200]	52	85.25	583	93.88
	(200, 500]	4	6.56	38	6.12
	(500, + ∞)	5	8.19	0	0.00
X_5	[0, 0.5]	7	11.47	94	15.14
	(0.5, 1.0]	6	9.84	17	2.74
	(1.0, 1.5]	2	3.28	18	2.89
	(1.5, 2.5]	46	75.41	492	79.23
X_6	[0, 500]	41	67.21	474	76.33
	(500, 1500]	1	1.64	18	2.89
	(1500, + ∞)	19	31.15	129	20.78
X_7	[0, 30]	43	70.49	374	60.23
	(30, 50]	11	18.03	128	20.61
	(50, + ∞)	7	11.48	119	19.16
X_8	[0, 200]	56	91.80	469	75.52
	(200, 500]	2	3.28	97	15.62
	(500, + ∞)	3	4.92	55	8.86
X_9	[0, 500]	49	80.33	448	72.14
	(500, 1000]	12	19.67	173	27.86
	(1000, + ∞)	0	0.00	0	0.00
X_{10}	[0, 100]	21	34.42	0	0.00
	(100, 150]	2	3.28	171	27.54
	(150, + ∞)	38	62.30	450	72.46
X_{11}	[0, 16]	43	70.49	423	68.12
	(16, 30]	11	18.03	120	19.32
	(30, + ∞)	7	11.48	78	12.56
X_{12}	[0, 16]	11	18.03	75	12.08
	(16, 30]	26	42.62	276	44.44
	(30, + ∞)	24	39.35	270	43.48
X_{13}	[0, 5]	16	26.23	88	14.17
	(5, 10]	42	68.85	408	65.70
	(10, 20]	3	4.92	123	19.81
	(20, + ∞)	0	0.00	2	0.32
X_{14}	[0, 5]	61	100.00	621	100.00
	(5, 30]	0	0.00	0	0.00
	(30, 100]	0	0.00	0	0.00
X_{15}	(0, 144)	49	80.33	432	69.57
	144	3	4.92	31	4.99
	(144, + ∞)	9	14.75	58	9.34

X_1: Distance to disturbance zone with frequent human activity (km), X_2: Distance to disturbance zone with infrequent human activity (km), X_3: Distance from a lake (m), X_4: Lake area (m^2), X_5: Distance from burnt zone (km), X_6: Burnt area (m^2), X_7: Distance to remnant reed cluster (m), X_8: Remnant reed cluster area (m^2), X_9: Remnant reed cluster density (stain/m^2), X_{10}:(cm) Remnant reed cluster height, X_{11}: Water depth (cm), X_{12}: Vegetation height (cm), X_{13}: Vegetation density (stain/m^2), X_{14}: Vegetation coverage (%), X_{15}: Altitude (m).

Table 2. The significance comparison on the environmental variables between Red-crowned Cranes nest-site and comparison plot sampled

Environmental variables	Red-crowned Crane	Comparison plot	t
X_1	2150±176	2697±72	-2.879**
X_2	761±82	1023±33	-2.962**
X_3	81.0±17.3	143.5±3.3	-5.319**
X_4	87.5±25.1	27.1±2.1	2.400*
X_5	1949±107	2058±35	-0.469
X_6	1101±213	2525±199	-4.884**
X_7	34.2±6.0	33.2±0.9	0.278
X_8	91.4±31.5	190.6±13.2	-2.296*
X_9	309±34	437±11	-3.657**
X_{10}	127.0±9.6	178.6±1.4	-5.345**
X_{11}	13.0±1.7	13.4±0.5	-0.219
X_{12}	33.1±3.0	31.4±0.6	3.340**
X_{13}	697±27	833±12	0.760
X_{14}	0.52±0.07	0.30±0.01	-3.675**
X_{15}	139.2±0.7	141.6±0.2	-3.134**

**: $p<0.01$, *: $p<0.05$.

X_1: Distance to disturbance zone with frequent human activity (km), X_2: Distance to disturbance zone with infrequent human activity (km), X_3: Distance from a lake (m), X_4: Lake area (m^2), X_5: Distance from burnt zone (km), X_6: Burnt area (m^2), X_7: Distance to remnant reed cluster (m), X_8: Remnant reed cluster area (m^2), X_9: Remnant reed cluster density (stain/m^2), X_{10}:(cm) Remnant reed cluster height, X_{11}: Water depth (cm), X_{12}: Vegetation height (cm), X_{13}: Vegetation density (stain/m^2), X_{14}: Vegetation coverage (%), X_{15}: Altitude (m).

The data reduction of environmental variables in the nest-site habitat

We carried out the Factor Analysis of 15 environmental variables in the nest-site habitat for Red-crowned Cranes. The result of Data Reduction indicated that the eigenvalues of the first six factors are greater than 1 with less relativity, and the eigenvalues of the other factors are all less than 1 with more relativity (Fig. 2). The accumulative contribution rate of the first six factors reaches to 70.26%, indicating that the first six factors include most information of all 15 environmental variables basically, and can reflect the primary factors that influence the nest-site selection for Red-crowned Cranes. Thus, we took the first six factors calculated the relevant eigenvectors (Table 3). The six factors are respectively defined as fire factor, concealment factor, disturbance factor, hatch conditions, nest material factor, and food factor.

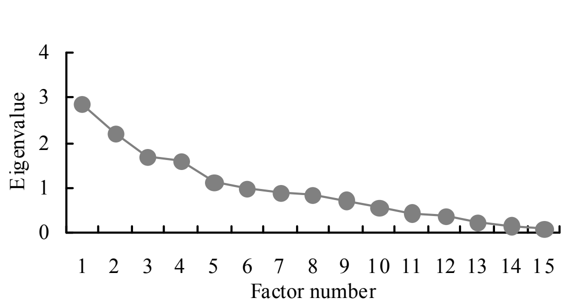

Fig. 2 The eigenvalues of factors analysis on nest-site habitat variables of Red-crowned Cranes

Table 3. The principal component analysis of nest site habitat factors on the Red-crowned Cranes

Environmental variables	Component					
	Fire factor	Concealment factor	Disturbance factor	Hatch conditions	Nest material factor	Food factor
Eigenvalue	2.885	2.215	1.692	1.611	1.134	1.002
% of variance	19.236	14.764	11.279	10.740	7.561	6.681
Cumulative %	19.236	34.000	45.278	56.018	63.579	70.260
X_1	-0.078	-0.164	0.706	-0.077	0.333	-0.206
X_2	0.095	-0.282	0.830	-0.087	0.015	0.036
X_3	0.338	-0.147	-0.179	-0.205	0.303	0.631
X_4	-0.169	0.006	0.009	0.046	-0.192	0.849
X_5	0.873	0.030	0.081	-0.026	-0.173	0.051
X_6	-0.864	-0.052	-0.084	0.100	0.149	-0.090
X_7	0.413	-0.013	-0.273	0.233	0.077	-0.024
X_8	-0.208	0.174	0.090	0.006	0.826	-0.050
X_9	0.082	0.909	-0.108	-0.150	0.183	-0.031
X_{10}	-0.113	0.922	-0.150	0.117	-0.005	-0.043
X_{11}	-0.191	-0.058	-0.248	0.604	-0.294	-0.013
X_{12}	-0.047	0.049	0.027	0.793	0.073	-0.026
X_{13}	0.726	-0.146	-0.177	-0.251	0.047	-0.164
X_{14}	0.129	-0.326	-0.543	-0.345	0.231	-0.019
X_{15}	0.489	-0.149	0.242	0.501	0.259	-0.069

Discussion

In the Zhalong Nature Reserve, a drought status persisted between 1997 and 2001 (except flood in 1998). The wetlands were severely devoid of water and the habitat became severely degraded (Han et al. 2005). The drought had a dramatic consequence on the reed swamps. More specifically, the area of reed swamp became smaller and the reed vegetation became lower and thinner. The reeds remained the main economic source for local residents; however, those low and thin reeds became remnant reeds because of small economic value and an increasing area with the aggravation of drought and lack of water. Local residents burned these remnant reed clusters for better germination. During the periods of August - October 2001 and March 2002, fires swept through a large area of the Zhalong wetlands (Zou et al. 2007b) and burned 80% of the core area as a result of the very evident lack of water in Zhalong wetland. In April 2002, a long-term water replenishing mechanism was set up in Zhalong wetland (Zou et al. 2003) and water replenishing exceeded 1.2 billion m^3 in the continuous six years, which had a great restoration effect on the degenerative state. It can be said that water lack resulted in drought and fire, and its present restoration efforts keep Zhalong wetland in the special state. Annual fires in the remnant reed cluster create large fluctuations in habitat quality in the Zhalong wetlands. These special environment conditions make an effect on the nest-site selection for Red-crowned Cranes (Li *et al*. 2005) and Red-crowned Cranes also must produce a definite adaptive strategy about the nest-site selection.

Factor analysis of environmental variables

Fire factor: the variable coefficients are larger for the distance from burnt zone, the burnt area, the distance to remnant reed cluster, and vegetation density. The burnt zone is very open and not well covered (the black burnt zone is not favorable for Red-crowned Cranes with white body color to nest), and it does not provide nest materials for Red-crowned Cranes, and in turn-therefore, this zone is not used for nesting. It can be seen from the two environmental variables namely the distance from burnt zone (1 949±107 m) and the burnt area (1 101±213 m^2) that the breeding Red-crowned Cranes are sensitive to the burnt zone and they avoid this habitat condition. Red-crowned Cranes select un-burnt zones with ample nesting materials and remnant reed cluster to nest. Therefore, the distance to remnant reed cluster (34.2±6.0 m) is a good explanatory variable. The remnant reeds cluster is low and rare (309±34 stains/m^2), while the high and dense reeds will be reaped. So, the vegetation density around the remnant reed cluster is relatively high (697±27 roots/m^2). Ideal conditions for Red-crowned Cranes usually are zones that are far from burnt zones and with remnant reed cluster. However, selection of burnt zones appears to be a fast adaptive tactic used by the breeding Red-crowned Cranes. The four environmental variables, namely the distance from burnt zone, the burnt area, the distance to remnant reed cluster and vegetation density, are also the result of selective adaptation. The selective adaptation appears to be due to conditions created by fire.

Concealment factor: Field investigation found that the location of remnant reeds is usually between the nest and the burnt zone. This location benefits the breeding Red-crowned Cranes because it conceals the incubating pair and compensates for the openness of the burnt zone. The height of remnant reeds (127.0±9.6 m) exceeds the height of Red-crowned Cranes when they are sitting on the nest (the neck length of Red-crowned Cranes is 40−50 cm, and body height is 20−30 cm, for a total of 60−80 cm), being aid in the concealment of Red-crowned Cranes. In addition, the sparse density and the clear visibility of remnant reeds also provide concealment. Both the variables contribute to the concealment of Red-crowned Cranes when it sits in the nest.

Disturbance factor: The variable coefficients of the distance to disturbance zone with frequent human activity, the distance to disturbance zone with infrequent human activity, vegetation coverage are larger. The zone with infrequent human activity refers to an area where the frequency of man-made movement is low, (e.g., small scale fishing or the location of a large driveway). The zone with frequent human activity refers to an area where the frequency of man-made movement is high (e.g., villages, roads). All activities in these zones create a disturbance for hatchling Red-crowned Cranes even though they are normal activities of the local residents. Red-crowned cranes require a large distance between such disturbances. We found the distance from the disturbance zone with infrequent human activity and frequent human activity is 761 m (±82 m) and 2 150 m (±176 m). Vegetation coverage in the area is accordingly higher, in correspondence with the higher vegetation density in the Fire factor.

Hatch conditions: The variable coefficients of water depth, vegetation height and altitude are larger. The vegetation height is defined as the height of reed stubble. Our investigation found that water depth is lower than vegetation height. Because of the existence of reed stubble, there is a regular isolate air layer between the bottom of the nest and the ground, which is favorable for maintaining a constant temperature when Red-crowned Crane chicks are hatching. In addition, the influence of solar radiation and ground reflection causes a temperature change in the local micro-environment, which forces the water in the bottom of the nest to evaporate, creates a constant high humidity within the nest. Data regarding water depth (13.0±1.7 cm) and vegetation height (33.1±3.0 cm) demonstrates that the altitude (139.2 ± 0.7 m) with open water is often comparatively lower than the altitude of the whole area. Temperature and humidity are the two necessary conditions for the hatching. We found that vegetation height, water depth, and altitude contribute to the constant and ideal temperature and humidity requirements for Red-crowned Crane hatching. These factors are useful for enhancing the success rate of Red-crowned Cranes' hatch.

Nest material factor: Our investigation found that the area of remnant reeds is related to the size of nest. For instance, if the remnant reed area is larger, then the nest is larger and more intact and conversely, if the remnant reed area is smaller, the nest is smaller and simpler. If there are no remnant reeds at all, then the nest tends to be fairly crude, with little nesting material or the nest would be located on a small hillock.

Food factor: the variables coefficients of the distance from a lake and the lake area are larger. The lake in this paper refers to seasonal lakes. Within the lake area, there is the potential for the cranes to catch fish and prawns, which can make up for food shortages for the hatchling Red-crowned Cranes. For instance, when food supply is inadequate, the hatching crane would replenish energy in lake closer to nest-site. The lake became the main food gathering source for Red-crowned Cranes during this period.

Nest-site habitat types

Reed swamps are the main vegetation type in Zhalong Nature Reserve. Reeds have the unique characteristics of tall and straight stalk (1−3 m high), which is not found in other plants. These characteristics also make the reeds very suitable for the nesting material for the large bodied Red-crowned Cranes. Moreover, the tender buds of reeds in spring, in addition to abundant insects and fish found in reed swamps during summer can provide all resources needed for Red-crowned cranes during the breeding season. In essence, it is necessary for Red-crowned Cranes to select reed swamps for nesting (Wan et al. 2002; Zou et al. 2003). However, the results of this investigation showed that 6.85% Red-crowned Cranes nest in other habitats such as sedge swamp, carex pseudo-curaica swamp and burnt zone (there are below 1 m^2 puddles and below 10 m^2 remnant reeds cluster). These special cases all appeared in 2002 after the large fire. During August - October 2001 and March 2002, a large-area fire burned 80% of the core area in Zhalong Nature Reserve and

resulted in a vast extent of degraded nesting habitat for Red-crowned Cranes. These Red-crowned Cranes returned from the wintering grounds and had nowhere to nest and no time to seek new nesting locations. This exerted a pressure on the pairs to adapt novel habitat types (sedge swamp, carex pseudo-curaica swamp and burnt location) to nest. This demonstrated the adaptable behavior of Red-crowned Cranes to fluctuating conditions (Li et al. 1999). It may be possible that Red-Crowned Cranes will use a wider variety of nesting habitats such as reed swamps, sedge swamps, carex pseudo-curaica swamps and burnt zones. However, this study indicates that sedge swamps, carex pseudo-curaica swamps and burnt zones are utilized only under special conditions and that the main nesting habitat type remains reed swamps.

Nest-site habitat selection

Fire has been shown to dramatically influence nest site selection of Red-crowned Cranes as compared with other forms of environmental disturbance (drought or water replenishment) (Zou et al. 2003). Red-crowned Cranes however have shown some adaptability to fire-disturbed nesting habitats. Although concealment and disturbance both negatively influence Red-crowned Crane incubation, they have different effects. Concealment is an instinctive behavioral response taken by a wild animal during different periods in its life history to ensure reproduction and viability (Feng et al. 2005; Hou et al. 2007). Concealment factors hide both the cranes and the nest. Disturbance factor lays emphasis on the external disturbance and was only measured by the active remote way. It can be said that both the factor selections provide double safeguard for breeding safety of Red-crowned Cranes. The two factors both concern safety matters when Red-crowned Cranes are hatching and can be combined into security factor. For Red-crowned Cranes, when choosing nest-site, some factors like nesting material, incubation humidity and incubation temperature all have relations with practicality of nesting. Nesting material is the platform on which eggs are laid and incubated, so it has a direct effect on incubation quality. Incubation humidity and incubation temperature are two factors affecting successful incubation (Ji et al. 2001; Qiao et al. 2002). Therefore, nest-material factor and incubation conditions have connections with eggs' incubation and can be combined into incubation factor. Field investigation has also found that when foraging, newly hatched Red-crowned Cranes will leave the nest and temporarily feed around the nest. In the prophase of brooding, the adult Red-crowned Cranes will lead the young Red-crowned Cranes to feed round the nest. The foraging area gradually broadens with the growth of the young Red-crowned Cranes. It is thus clear that the food factor includes food and water. From a certain perspective, it may be considered that the nest-site habitat for Red-crowned Cranes include five factors: fire, safety, incubation, food and water, and four selection factors, namely fire factor, security factor (concealment factor and disturbance factor), incubation factor (incubation conditions and nest-material factor) and food factor. It is in accordance with the demands of the three elements (food, water, cover) on habitat selection for animals (Lu 2004, Yang et al. 2006, Dai et al. 2007).

Nest-site habitat selection pattern

Animal habitat selections involve two processes: (1) the rough selection of the general features of environment in different environment, (2) then selection of the subtle features of environment. Various selection patterns of bird habitats were constructed in the previous studies (Thereinto and Svardson 1949; Hilden 1965). Johnson (1980) defined four orders of habitat selection that are hierarchical in nature and provide a useful empirical framework for habitat studies, namely the geographical or physical range of a species (first-order selection), home range of individual or colony within geographic range (second-order selection), the different habitat type used by animal within territories or home range (third-order selection) and the actual attainment of food items or selection of nest sites from those available (fourth-order selection). Chu et al. (1993) considered avian habitat selection at three levels: the geographic region, the life environment within geographic region, and the site for all kinds of life activities within life environment. Yang et al. (2000) considered that avian breeding habitat selection especially nest-site selection mainly depends on vegetation structure within a small scale, for instance, vegetation coverage around the nest-site, vegetation height and visual openness. In addition, many critical reviews on avian habitat selection pointed out that the scale influence the perception of habitat availability and the sense of habitat selection (Kotliar et al. 1990; Orians et al. 1991; Wei et al. 1998; Clark et al. 1999; Jones 2001; Zhang et al. 2005). The above mentioned animal habitat selection theories all contain both the macro-habitat or large habitat and the micro-habitat or small habitat selection. Nest-site selection for Red-crowned Cranes should follow the similar pattern of habitat selection in the two orders (the large habitat and the small one). If the nest-site habitat selection for Red-crowned Cranes is based on this pattern, there is the following analysis: the large habitat selection order contains two selection processes, in which the first process is the selection of large geographical region, namely Zhalong wetland (Songnen Plain), and the second is the selection of habitat types in geographical region, namely reed swamps. The small habitat selection order contains two selection processes, in which, the first selection process is selection of available zone in habitat types, namely nest zone selection (fire factor and disturbance factor within security factors), and the second is the site used for the actual nest, namely the selection of nest-site micro-habitat (concealment factor within security factors, incubation factors namely hatch conditions and nest material factor, and food factors). The available habitat should be able to insure successful incubation. So, the available habitat should take on three conditions: little or no disturbance, incubation elements and brooding elements. It can be seen from the above analysis that the main influence factors of the nest-site micro-habitat selection for Red-crowned Cranes include fire factor, incubation factors (nest material factors and incubation condition), security factors (concealment factors and disturbance factors) and food factors.

In addition, both the fire factor and security factor concerns disturbance. Incubation factor relates to the incubation element. Food factor has a direct relationship to the brooding element. The factor is corresponding to three conditions of the available habitat, which can guarantee the task and purpose that Red-crowned Cranes selects the site to nest.

Conclusions and suggestions

In Zhalong Nature Reserve, northeast China, the nest-site selection pattern of Red-crowned Cranes included both the macro- and micro-habitat orders and three choices: nest-site habitat type, nest zone selection, and nest-site microhabitat selection. Within the nest-site habitat types of Red-crowned Cranes, reed swamp (93.15%) is selected as the nest habitat prior to Carex swamps and Carex pseudoeuraica marshes, and reed fire districts. The Factor Analysis revealed that the selection of nest-site micro-habitat should consider four basic environmental factors: fire factor, security factor (concealment factor and disturbance factor), incubation factor (incubation conditions, nest-material factor), and food factor. Further analysis revealed that fire, the remnant reeds cluster and water are the main elements for the nest-site habitat selection of Red-crowned Cranes in Zhalong Nature Reserve. We suggest that the three elements should be managed scientifically by the manager of Zhalong Nature Reserve to design a management strategy for the timely conservation of Red-crowned Crane and its survival wetland resource.

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